# PATENT SPECIFICATION

DRAWINGS ATTACHED

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## COMPLETE SPECIFICATION

## Dynamoelectric Machine

I, ALEXANDER WALDEMAR COCHARDT, a citizen of the United States of America, of R.D. 3, Box 233, Export, Pennsylvania, United States of America, (formerly of 697 Lauda, Gartenstrasse, 42, Germany), do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement: —

The invention relates to dynamo-electric machines.

Two-pole d.c. motors with two permanent magnets in the stator, have been constructed in the past in which the two permanent magnets are sandwiched between two iron segments in the stator. The iron segments constitute both the mutual pole shoes and the stator frame. The flux of both permanent magnets is combined and is caused to pass through the iron segments into the rotor. Due to the parallel arrangement of the two permanent magnets the permanent magnet flux reaching the rotor is essentially doubled and the power rating of the machine is increased by a factor of nearly two.

A major disadvantage of these prior-art machines is due to the occurrence of a considerable leakage flux which by-passes the usable flux linking the armature winding; hence the efficiency of such prior-art d.c. machines is low. Also, more recently developed high-energy permanent magnets on ferrite basis, such as those described in my application for British Letters Patent No. 37402/61 (Serial No. 995374), do not lend themselves for effective incorporation in the prior-art machines in that the stator would have to be made excessively long in one direction. Furthermore, the provision of interpoles needed in certain larger-size d.c. machines involves considerable design difficulties.

The invention resides in a dynamo electric machine comprising a stator member and a rotor member concentrically arranged within the stator member so as to define a magnetic gap between said stator and rotor members, said stator member including a magnetically conducting stator frame having a substantially closed cross-sectional configuration and a plurality of permanent magnets disposed within said stator frame, said permanent magnets having their one pole faces in direct contact with said stator frame and having their other pole faces in direct contact with at least one magnetically conducting pole shoe bordering said magnetic gap, at least two adjacent ones of said permanent magnets being in direct contact with a single common pole shoe whereby the magnetic fluxes of the said at least two adjacent permanent magnets are combined in said common pole shoe and the combined flux is caused to pass from said common pole shoe through said magnetic gap into said rotor, the arrangement being such that the interfaces between said common pole shoe and the permanent magnets in direct contact therewith define angles less than 180°.

The invention is particularly applicable to two-pole or multi-pole permanent magnet d.c. machines. It was found that in the arrangement of the present invention there is essentially no magnetomotive force between the opposite sides of the stator frame. Consequently, there is essentially no leakage flux emanating from the stator frame, and the efficiency of the system is very high. The mutual pole shoes serve four functions. They greatly concentrate the permanent magnet flux into the useful magnetic gap between stator and rotor. Gap flux densities as high as 7000 gauss have been accomplished with inexpensive, low-remanence-type ferrite magnets. They protect the permanent magnets from being demagnetized by momentary, excessive armature currents. They allow the use of magnets with simple, rectangular shapes which can

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be made to exhibit high energy at low cost. They provide an economical solution to the problem of obtaining a small air gap and a high gap permeance with extremely brittle permanent magnets.

The invention will become more readily apparent from the following detailed and exemplary description in connection with the accompanying drawings, wherein:

Fig. 1 shows a cross-section of a two-pole d.c. motor structure perpendicular to the axis.

Fig. 2 shows the section A—A of Fig. 1.

Fig. 3 shows a cross-section of a four-pole d.c. motor structure.

Fig. 4 shows a modified pole shoe for the machines of the invention.

The d.c. motor of Fig. 1 comprises a stator 1 and a rotor 2. The stator 1 comprises four permanent magnets 3, 4, 5, and 6, a stator frame 7, and pole shoe pieces 8, 9, 10, and 11. The permanent magnets are arranged in the stator with the two pole faces of each permanent magnet in direct contact with the stator frame 7 and the pole shoe pieces, respectively. As shown, the stator frame 7 is square-shaped, although other shapes having a substantially closed cross-sectional configuration may be used. The rotor 2 contains a shaft 12 and, mounted on said shaft, a stack of laminations 13 with armature slots 14 and teeth 15. The armature winding is not shown in Fig. 1. The two pole shoe pieces 8 and 9 constitute one common pole shoe and the two pole shoe pieces 10 and 11 constitute the second common pole shoe of the two-pole embodiment. Obviously, only one piece could be used for each pole shoe instead of the two pieces shown in Fig. 1. In order to reduce the flux shifting in the pole shoes due to armature cross-fields and to facilitate the pressing of such pieces, pole shoe slots 16 and 17 may be provided.

The direction of magnetization of the four permanent magnets 3, 4, 5 and 6 is indicated by the symbols N and S. The two permanent magnets 3 and 4 are arranged magnetically parallel to each other as are two permanent magnets 5 and 6. Due to the magnetically parallel arrangement the permanent magnet flux passing into the rotor 2 is essentially doubled, and the power rating of the machine is increased by a factor of nearly two. Due to the fact that the stator frame 7 is substantially closed, there is essentially no magnetomotive force either between opposite sides of the stator frame 7 or between adjacent stator frame sides, the left hand and upper stator frame sides providing an effective magnetic short circuit between the north pole of magnet 6 and the south pole of magnet 3, and the lower and right hand stator frame sides providing an effective magnetic short circuit between the north pole of magnet 5 and the south pole of magnet 4. It is emphasized that these magnetic short circuits are included in and form part of the respective main flux paths. Also, since the left hand and lower stator frame sides and the right hand and upper stator frame sides are at substantially the same magnetic potentials respectively, essentially no flux passes through corners 18 and 19. Thus the leakage factor of the arrangement of Fig. 1 is small, and the efficiency of the machine is very high.

The armature winding 22 is indicated in Fig. 2. The brushes, bearings, etc. (not shown in Fig. 2) can be attached to the end plates 23 and 24. As is evident from Figs. 1 and 2, the pole shoe pieces 8, 9, 10, and 11 may taper down to the rotor surface in all four directions, thereby enhancing the concentration of the flux emanating from the permanent magnets 3, 4, 5 and 6 onto the rotor surface. In a typical dynamo-electric machine of the invention the flux density in the magnetic gap between stator 1 and rotor 2 is about 7000 gauss which is two to six times more gap flux density than in the prior-art ferrite d.c. motors.

The stator frame 7 is made from a magnetically conducting material, such as iron or low-carbon steel. It can have other forms than that shown in Fig. 1. For example, it can be rectangular or round. Similarly, there can be more than two magnets arranged magnetically in parallel on each common pole shoe, for example, three or four. A magnetically parallel arrangement of more than two magnets on each common pole shoe is desirable in combination with a stator frame that is round on the outside and hexagon- or octagon-shaped on the inside. Still another embodiment of a two-pole dynamo-electric machine may include a stator frame consisting of a regular 8-cornered tube and eight permanent magnets arranged in two groups of four each, the four magnets of each group being respectively joined in a magnetically parallel manner to the two common pole shoes of the two-pole structure.

The permanent magnets preferably are anisotropic ferrite permanent magnets, such as, for example, the modified strontium ferrite magnets as described in my aforesaid application for British Letters Patent No. 37402/61 (Serial No. 995374). Preferably, these magnets should have shapes of rectangular parallelepipeds as shown in Figs. 1 and 2, i.e. each magnet preferably has six flat rectangular surfaces with each two opposite surfaces being essentially equal in size. It was found that inexpensive high-energy permanent magnets should approach such rectangular parallelepiped shapes as shown in my copending application for British Letters Patent No. 48315/63 (Serial No. 995375). Examples of other permanent magnets suitable for the machines of the present invention include Pt-Co-alloy magnets (Pt—23%Co) and other metallic permanent

magnets such as those known under the trade name ALNICO.

The pole shoe pieces 8, 9, 10, and 11 are made of a magnetically conducting material, preferably of a sintered, iron-containing material which is coined to shape after the sintering operation so that no machining is required. If the motor is to operated at high speeds, the electric resistivity of the pole shoes should be high. Exemplary pole shoe pieces having a high electrical resistivity are composed of an iron-powder-core material, of densely sintered silicon-iron, or of plastic-bound magnetic powder. The pole shoe pieces may, of course, also consist of laminated structures. Pole shoe pieces consisting of solid magnetic steel are feasible when the speed of the machine is not high. The end plates 23 and 24 can be made, for example, of a magnetically good conducting material. Part of the return flux is then carried through the end plates 23 and 24. The motor can then be made smaller because the wall thickness of the stator frame 7 can be reduced.

The motor of Figs. 1 and 2 can be assembled as follows: A piece of square tubing is cut for the stator frame 7. The unmagnetized four permanent magnets 3, 4, 5, and 6 are ground on only their two pole faces. The four pole shoe pieces 8, 9, 10, and 11, when consisting of sintered material, may be coined to shape. The permanent magnets are then fastened to the stator frame, and the pole shoe pieces are fastened to the permanent magnets, for example, by means of a glue or by means of die-casting a lead-base alloy around the various components. If necessary, the stator, subsequent to assembly, may be machined to the precise inside diameter desired.

The most suitable method for magnetizing the permanent magnets depends on the size of the motor and the magnetic characteristic of the permanent magnets. The permanent magnets can be magnetized prior to the assembly of the stator components for small-size motors if permanent magnets with a high coercive force and constant recoil permeability are used. If permanent magnets with a knee in the demagnetization curve are used and if the motor is small, the permanent magnets are preferably magnetized after the assembly of the stator frame and before inserting the rotor into the stator. By this means, a partial, permanent demagnetization of the permanent magnets is avoided. This has the added advantage that stator frame and pole shoe pieces can be made from a magnetically hard material because they would then be properly magnetized also.

For large machines permanent magnetizing coils are placed around each magnet, the rotor is placed into the stator structure, and only then the magnets are magnetized, preferably by a short current pulse from a condenser discharge magnetizer or a half-cycle magnetizer. This way, the large magnetic forces between stator and rotor become effective only after the final assembly of the motor. In addition, the use of permanent magnetizing coils allows the machine to be switched to different levels of flux or to be switched off completely at any time. When in larger machines the rotor has to be removed from the stator, for example, for purposes of repair, the magnets are at least partially demagnetized through the magnetizing coils. To facilitate assembling or disassembling of the rotor and stator when the magnets are magnetized and when no magnetizing coils are provided, wedge-shaped iron-pieces can be slid into the openings 25 and 26 of Fig. 1 prior to assembly or disassembly, said wedge-shaped iron pieces magnetically short-circuiting both pole shoes and thus strongly reducing the magnetic forces between stator and rotor.

The invention is also applicable to four-pole or higher-pole machines. At least two permanent magnets are arranged magnetically parallel so that their flux is combined and is caused to pass through a mutual pole shoe common to said two or more magnets. The permanent magnets are in direct contact with the stator frame and the pole shoes, respectively. Each pole shoe may consist of two or more pole shoe pieces or of a single pole shoe piece as shown in the arrangement of Fig. 3. In the embodiment of Fig. 3, the stator 27 contains eight permanent magnets 28 to 35. The flux of each pair of magnetically parallel magnets is combined and is caused to pass through a common pole shoe. For example, the flux of the permanent magnets 28 and 29 passes through the common pole shoe 36. The pole faces of the eight permanent magnets are in direct contact with the stator frame 37 and the pole shoes, respectively. The stator frame 37 consists of a piece of 8-cornered steel tubing. The rotor contains more armature slots 39 than the rotor of Fig. 1 because of the higher pole number. The arrangement of Fig. 3 is usually preferred over that of Fig. 1 if the rotor diameter is larger than six inches.

Interpoles and compensating windings, such as those needed for the operation of certain larger-size d.c. machines, can be used.

In a further modification of the machine of the invention, the pole shoes are provided with slots and/or holes, extending longitudinally in a direction parallel to the rotor axis. The slots are so arranged that the cross-sections thereof extend radially with respect to the rotor axis. There is less flux shifting in the pole shoes when such slots or holes are present. Fig. 4 shows an exemplary pole shoe 58 provided with slots 57. The pole shoe 58 can be made by punching the desired slots or holes into steel sheet if the pole shoe 58 is made from a stack of laminations.

In some machines of the invention it is

necessary that the permanent magnet flux passing into the rotor stays constant regardless of the operating temperature. For example, it may be required to keep the number of revolutions of a motor of the invention constant between—20 and 100°C. As is well known, the flux of all permanent magnets decreases with temperature. According to a further feature of the invention, compensating means can be provided for establishing a magnetic by-pass in relation to at least one of the permanent magnets, the magnetic by-pass consisting of a temperature-dependent magnetic material, such as a Fe—30% Ni—alloy. For example, wedge-shaped pieces of such an alloy may be fitted into the separations 25 and 26 of Fig. 1. In this way, the magnetic flux through the magnetic gap between stator and rotor may be kept substantially constant over the operating temperature range. Another method for the compensation of temperature effects consists in electrically connecting a negative-temperature-coefficient thermistor in series with the armature winding.

Apart from d.c. motors, the invention may be used in other dynamo-electric machines, such as d.c. generators, eddy current brakes, eddy current couplings, and synchronous magnetic couplings. The part denoted here as "stator" may rotate, and the part denoted here as "rotor" may be stationary. In, for example, eddy current couplings and synchronous magnetic couplings made according to the principle of the invention both "stator" and "rotor" rotate.

WHAT I CLAIM IS:—

1. Dynamoelectric machine comprising a stator member and a rotor member concentrically arranged within the stator member so as to define a magnetic gap between said stator and rotor members, said stator member including a magnetically conducting stator frame having a substantially closed cross-sectional configuration and a plurality of permanent magnets disposed within said stator frames said permanent magnets having their one pole faces in direct contact with said stator frame and having their other pole faces in direct contact with at least one magnetically conducting pole shoe bordering said magnetic gap, at least two adjacent ones of said permanent magnets being in direct contact with a single common pole shoe whereby the magnetic fluxes of the said at least two adjacent permanent magnets are combined in said common pole shoe and the combined flux is caused to pass from said common pole shoe through said magnetic gap into said rotor, the arrangement being such that the interfaces between said common pole shoe and the permanent magnets in direct contact therewith define angles less than 180°.

2. Dynamoelectric machine as claimed in claim 1, wherein said permanent magnets are magnetically anisotropic magnets of rectangular parallelepiped configuration.

3. Dynamoelectric machine as claimed in claim 1 or 2, wherein said permanent magnets are ferrite magnets.

4. Dynamoelectric machine as claimed in claim 1, 2, or 3, wherein said or each pole shoe consists of a sintered iron-containing material which is coined to shape.

5. Dynamoelectric machine as claimed in any of the preceding claims, wherein said or each pole shoe contains at least one slot extending longitudinally in the direction parallel to the axis of said rotor member.

6. Dynamoelectric machine as claimed in any of the preceding claims, wherein compensating means are provided for establishing a magnetic by-pass in relation to at least one of said permanent magnets, said compensating means consisting of a temperature-dependent magnetic material for maintaining the magnetic flux through said magnetic gap essentially constant over the operating temperature range.

7. Dynamoelectric machine as claimed in any of the preceding claims, wherein at least one of said permanent magnets is linked with a magnetizing coil provided for energization thereof whereby the flux level in said magnetic gap is variable by energizing said magnetizing coil with variable current pulses.

8. Dynamoelectric machine as claimed in any of the preceding claims, wherein interpoles are provided between each two adjacent pole shoes.

9. Dynamoelectric machine as claimed in any of the preceding claims, wherein said or each pole shoe contains compensating winding means.

10. Dynamoelectric machine as claimed in any of the preceding claims, wherein the cross-section of said stator frame, at least at the inside surface thereof, is of polygonal configuration, with the number of polygon sides corresponding to that of the number of permanent magnets.

11. Dynamoelectric machine, substantially as herebefore described with reference to the accompanying drawings and as illustrated in Figs. 1 and 2, Fig. 3, or Figs. 1 and 2 or Fig. 3 as modified in accordance with Fig. 4 thereof.

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FIG.1.

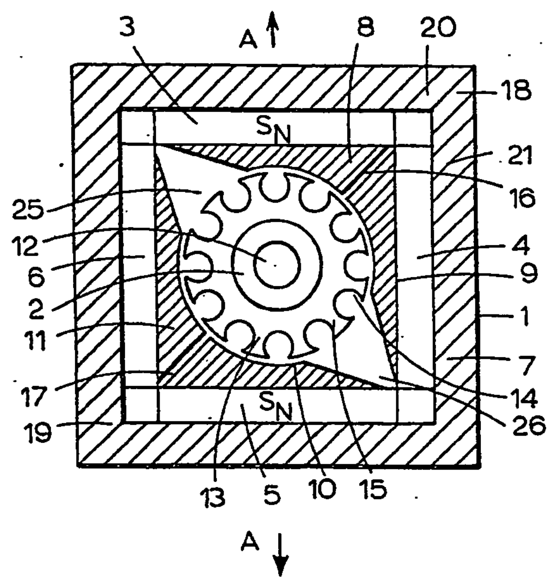

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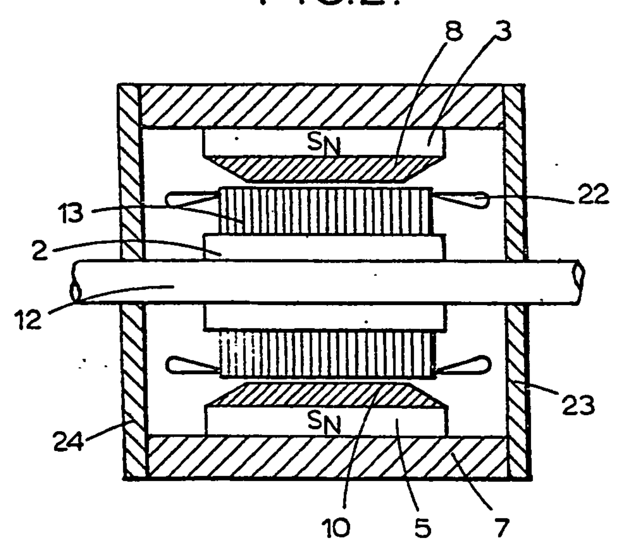
FIG.2.



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1018660 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

**Sheets 1, 2 & 3**

FIG. 3.

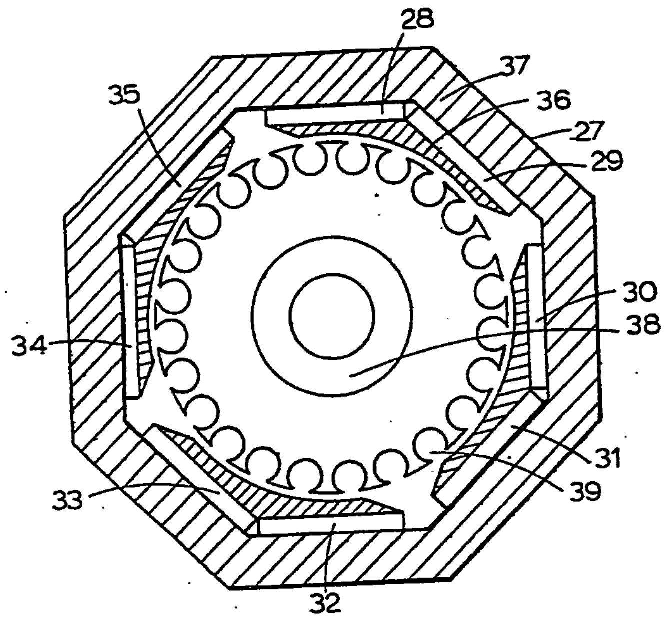



FIG. 4.

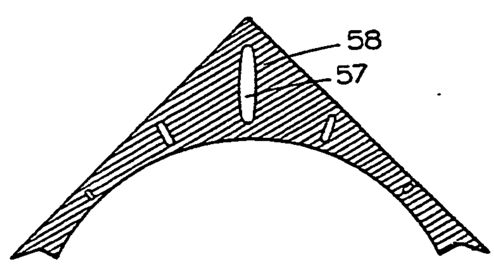

FIG.1.

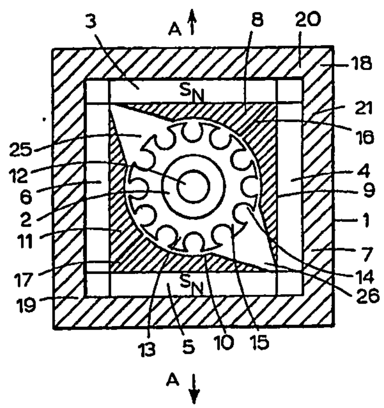


FIG.2.

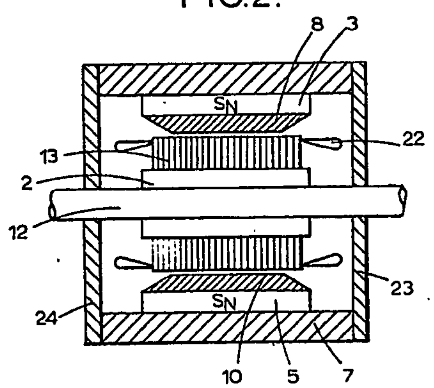


FIG.3.

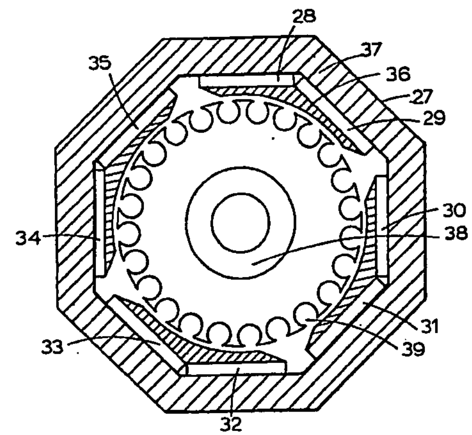


FIG.4.